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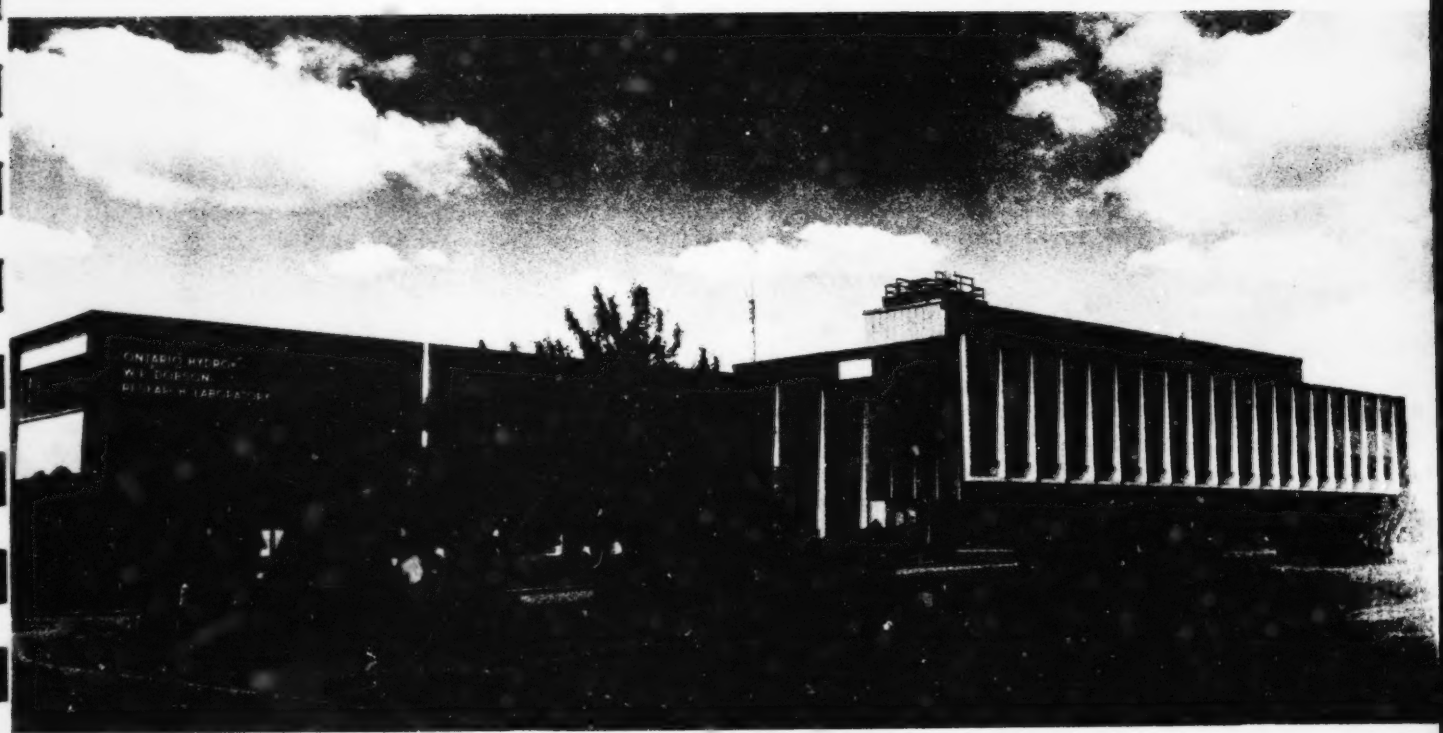

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COST REDUCTION POTENTIAL OF SOLAR DOMESTIC WATER HEATING SYSTEMS

Report No 83-218-K

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ABSTRACT

Cost reduction opportunities on both conventional and unconventional solar domestic water heaters were analyzed. Possible reductions in cost for solar equipment, installation hardware and labour were evaluated and the system types with the greatest cost reduction potential were identified. The solar collectors accounted for about half of the system manufacturing cost and therefore may offer the greatest cost reduction potential among the basic components of a system. The non-pressurized drain-back system, using unconventional low-cost collectors, offered the greatest opportunity for lowering the overall installed cost.

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To Mr. G.E. Patterson
Director of Energy
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COST REDUCTION POTENTIAL OF SOLAR DOMESTIC WATER HEATING SYSTEMS

1.0 INTRODUCTION

Of the many solar energy applications on the market today, residential solar water heating is generally considered to be the most commercially viable. While the sun's energy is free, the technology needed to harness it is very expensive at the present time. There are considerable efforts being made towards lowering the costs of system hardware and installation.

This study, part of Ontario Hydro's on-going solar program, had the following objectives:

a) To identify the types of solar systems with the greatest potential for development into low cost installed systems.

b) To evaluate the potential reduction of costs for solar equipment, installation hardware and labour.

In this study, only solar systems that can operate year-round in Canadian climate were examined. Seasonal systems such as simple thermosyphon solar water heaters were not considered.

The report shows various methods of reducing solar system capital and installation costs. It also can be used as a basis for evaluating the types and the amount of incentives necessary to stimulate the solar domestic water heating industry. In order to understand the need for an evaluation of cost reduction opportunities for residential solar water heating systems, several related topics are briefly discussed in Appendix A1.

2.0 COST ANALYSIS OF SOLAR DOMESTIC WATER HEATING SYSTEMS

During June/July 1982, manufacturers of solar domestic water heating systems (both conventional and refrigerant-charged) were contacted regarding the cost breakdown for an installed residential solar system.

The average installed cost was $4,178 for a conventional system and $3,870 for a refrigerant-charged system. Comparative results of the installed system cost structure are given in Figures 1 and 2.

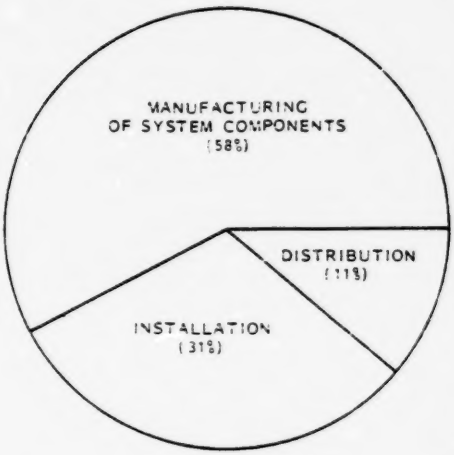

FIGURE 1
COST ANALYSIS OF CONVENTIONAL SYSTEM

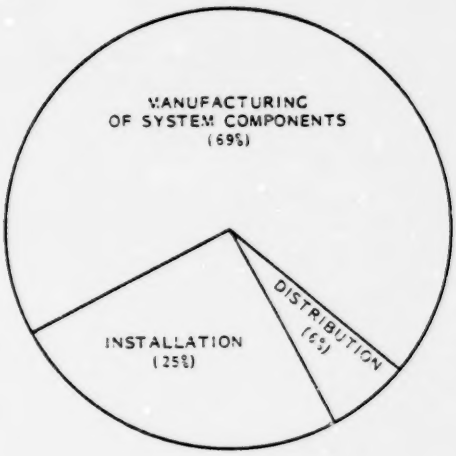

FIGURE 2
COST ANALYSIS OF
REFRIGERANT-CHARGED SYSTEM

Since the manufacturing cost represented the largest portion of the installed system cost, it was examined in more detail. Figures 3 and 4 show the manufacturing cost breakdown for conventional and refrigerant-charged systems respectively.

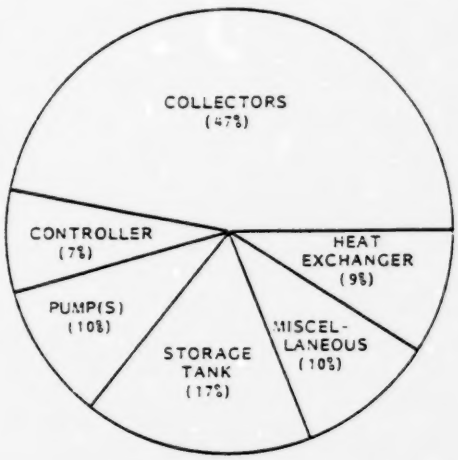

FIGURE 3
MANUFACTURING COST BREAKDOWN
(CONVENTIONAL SYSTEM)

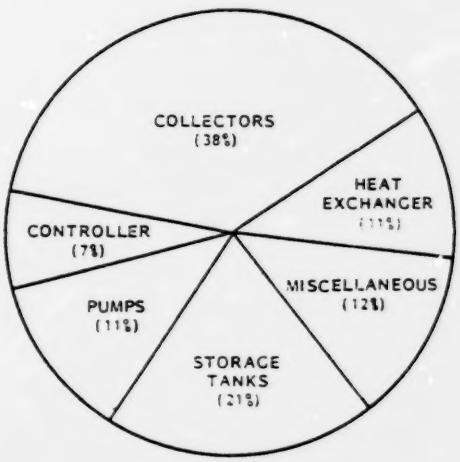

FIGURE 4
MANUFACTURING COST BREAKDOWN
(REFRIGERANT-CHARGED SYSTEM)

For more details on the procedures and findings of the survey, see Appendix A2.

3.0 SURVEY OF MATERIALS USED FOR SOLAR DOMESTIC WATER HEATING SYSTEMS

In the preceding section the cost breakdowns for conventional and refrigerant-charged solar domestic water heating systems were examined. The results were used to identify areas that would offer the greatest potential for cost reduction.

In this section, both standard system components and materials for the manufacture of collectors were investigated. Their cost and feasibility of application were examined along with the potential for cost reduction.

A study on the cost of constructing a solar collector was carried out. The unit cost for a collector ranged from $114 to $160 per square metre. Figure 5 shows the distribution of costs as a result of this study.

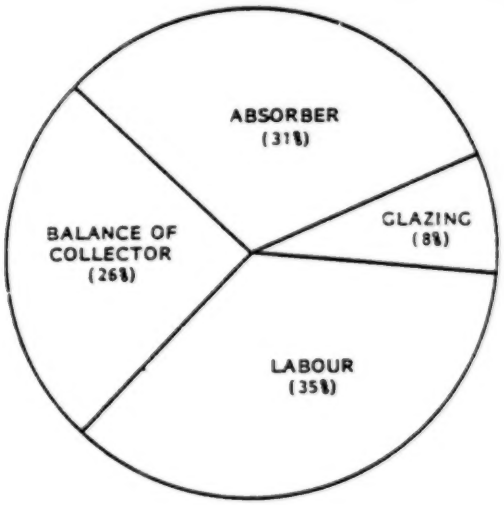

FIGURE 5
COST BREAKDOWN OF SOLAR COLLECTOR

Similar cost studies performed by manufacturers indicated a further 10% reduction potential in the cost of the collector (Appendix A3). Further reductions may be achieved with the increase of production level/1/:

Production Level (number of panels)	Percentage Reduction in Cost (%)
<10,000	<8%
50,000 - 75,000	8%
150,000 - 200,000	25%

Other topics that were surveyed and analyzed included the following: unconventional collectors/systems, storage tanks/heat exchangers, balance of systems components and installation. These topics are elaborated in more detail in Appendix A3.

3.1 Installation

For the conventional system, the materials required for plumbing ranged from $280 to $465 depending on both the size of the dwelling (number of floors, etc) and the distance between the collector array and storage tank. The materials used for this estimate are

generally available locally. The labour cost associated with the installation of such a system depends on several factors: the size of the installation, the experience of the installation crew and the company overhead. The time for such an installation could range from 20 to 40 person hours and the hourly rate range from $15 to $30 which indicates a considerable spread in the labour charges. The installation cost including materials could range from roughly $600 to $1700. With a well thought out installation procedure and experienced installers working in close association with the manufacturer, installation costs to the consumer could be in the lower half of the range.

A saving of 10 to 15% in material cost may be achieved by using 13 mm (1/2") diameter piping instead of 20 mm (3/4") pipes. The use of polybutylene tubing could reduce the tubing costs by roughly the same percentages without reducing the tube diameter. Factory assembled modules (ie storage tank/heat exchanger, pump(s), controller, etc) could limit the installation procedures to the handling of the major components and the running of the long lengths of tube only. With labour charges being at a premium, any time-saving innovations could greatly reduce the installation costs. There are some items on the market such as quick connectors which can reduce the installation time, but the cost of these items must be further reduced.

The installation cost for a refrigerant-charged system was found to be about the same as the conventional system. The use of soft copper or flexible aluminum in these systems could reduce the material costs by 5% and 8% respectively (Appendix A3).

4.0 EVALUATION OF SYSTEMS BASED ON THE SURVEY

A study on installed system costs was performed for three potential installations. The basic system types were listed as follows:

a) active closed loop system using antifreeze,

b) active closed loop system using refrigerant,

c) active drain-back system - 2 tanks (with non-pressurized polybutylene tank).

4.1 Results

The following results show the estimated minimum costs for various systems:

	Systems		
	Antifreeze Type	Refrigerant Type	Drain-back Type
Component Costs	$1472	$1320	$ 789
Installed Cost	$2647	$2442	$1725

The schematics of the systems and the details of the evaluation are given in Appendix D.

The following table represents a brief comparison of the three basic systems examined.

COMPARISON TABLE FOR EXAMINED SYSTEMS

Advantages	Disadvantages
a) Antifreeze Type	
- working fluid resists freezing - corrosion problem limited - best choice for storage tanks - pump work minimal ("low head" variety)	- double walled Hx suggested - working fluids must be tested and changed periodically - propylene-glycol (practically non-toxic) suggested
b) Refrigerant-Charged Type	
- simplistic design (few moving parts) - no need for freeze protection - use of latent heat - working fluid does not break down	- refrigerant is expensive - charging procedure more involved - double walled Hx suggested
c) Drain-Back Type	
- working fluid (water); inexpensive, good specific heat value, non-toxic - single walled Hx - simple charging procedure	- limited selection of non-pressurized storage tanks - pumps must be of "high head" variety - all collector loop components must resist corrosion

Hx - heat exchanger

4.2 Discussion of Results

Of the three proposed systems, the non-pressurized drain-back system (system c, section 4.0) provided the best potential for cost reduction. The estimates assume that cost savings are passed through to the consumers.

Innovative designs suggested that the cost for each collector could be below \$100 ($\$51/m^2$) including profit. The drawback here is that these low cost collectors must be used in open (non-pressurized) systems only, whereas the more expensive fintube and rollbond types have a broader range of application. With innovative collectors coupled with very carefully chosen balance of system components, a drain-back system could be purchased and installed for under \$2,000, which represents a 50% reduction in cost compared to systems on the market at the present time. Through mechanization and mass production, such a cost is feasible.

The closed-loop type of system employing antifreeze as a working fluid seems to be the most expensive of those systems examined. The installed cost might be reduced to about \$3,000 or even less, but the system requires the most maintenance. Although this price is roughly 25% lower than that of the survey average, it offers the least potential for further cost reductions.

The refrigerant-charged system appears to fall between the other two system types. The total installed cost could be about \$2,500, which represents about 35% reduction in cost. The absorber plate for this system is limited to either aluminum or steel due to possible compatibility problems if the refrigerant 11 is used with copper collectors.

For both the drain-back system and the antifreeze system, the cost for installation materials can be reduced by an additional 10 to 15% using polybutylene pipes. The installation cost for a refrigerant-charged system will remain in the same order of magnitude as for an antifreeze system because the installation technique and the hardware are basically the same.

5.0 CONCLUSIONS

5.1 Systems

5.1.1 The manufacturing cost represents the largest portion (about 50% for most systems) of the system's installed cost.

5.1.2 The non-pressurized drain-back solar system, using innovative low-cost collectors and simple storage system, offers the greatest opportunity for cost reduction (~50% reduction in cost). A complete system might be purchased and installed for under \$2,000.

5.1.3 Refrigerant-charged systems have a savings potential of about 35% due to their relatively simple operation (The installed cost may be reduced to less than $2,500.) Such systems can be either active or passive in nature, the latter being the least expensive.

5.1.4 Storage systems (including heat exchangers) designed strictly for solar applications could reduce the overall cost. The feasibility of new storage systems warrants further research.

5.2 Collectors

5.2.1 The collectors account for about half of the manufacturing cost and they offer the greatest potential for cost reduction.

5.2.2 Innovative designs for low-pressure liquid flat-plate collectors offer a good potential for cost reduction. The cost excluding installation is expected to be about $51/m^2$ of collector area.

5.2.3 Cost reductions of up to 25% ($196/m^2$ to $149/m^2$) may be expected for conventional solar collectors when using a fully automated facility with annual production levels of about 200,000 panels. If the production level is low (less than 10,000 panels per year) there is little opportunity for cost reduction.

5.3 Installation

5.3.1 Installation accounts for about one-third of the total installed system cost.

5.3.2 The installation cost for refrigerant-charged systems and conventional systems will be about the same as long as the installation technique and the hardware remain the same.

5.3.3 New materials and installation techniques warrant further research as installation represents a significant portion of the total installed cost.

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1. Booz, Allen and Hamilton, "Cost Reduction Opportunities: Residential Solar Systems". Final draft from Booze, Allen and Hamilton, 1979.

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3. Wilhelm, W.G., "Low Cost Solar Energy Collection for Cooling Applications". Brookhaven National Laboratory, June 1981.

APPENDIX A1

TOPICS RELATED TO COST REDUCTION IN SOLAR SYSTEMS

1. Canadian Solar Water Heating Industry

The first Canadian solar domestic water heaters appeared on the market in the mid-seventies. Since then, the market has been growing slowly with only a few leading manufacturers. All major solar porjects have been funded by either the federal or provincial government with little or no contribution from the private sector. The solar industry appears to be stagnated despite significant potential energy saving.

2. Cost Barrier and Cost Reduction Potential

The initial capital cost for a solar domestic water heating system is the major barrier to the widespread use of this technology. In addition, the uncertainty of obtaining a system that will provide at least fifteen years of maintenance-free operation prevents some customers from purchasing such systems. For customer acceptance, the system must be both cost attractive and reliable.

3. Ontario Hydro's Solar Program

At the present time, the primary objective of Ontario Hydro's solar program is to demonstrate ways with which to reduce the overall costs for solar domestic water heating systems. The program consists of the following steps:

a) establish the level to which the costs of systems can be reduced,

b) outline the methods required to reduce the costs and carry out product development,

c) transfer technology and information to all interested parties.

In addition to this, numerous complete solar systems were examined to determine the availability, performance, reliability and durability. The highest rated systems were in turn put into an actual field installation where over fifty systems have been examined.

APPENDIX A2

COST ANALYSIS OF SOLAR DOMESTIC WATER HEATING SYSTEMS

1. Method

During June and July of 1982, ten Canadian representatives of manufacturers of solar domestic water heating systems were contacted. They were all asked the same questions regarding cost breakdown for an installed system. These systems were required to supply a standardized daily volume of hot water (227 L), for a family of four, year-round.

The total installed system cost is a combination of costs due to: a) manufacturing, b) distribution, and c) installation. The first part, manufacturing, consists of costs for basic system components such as storage tanks, heat exchangers, pumps, etc, as well as material and labour costs for the production of the collectors and in some cases, labour costs associated with the assembly of pump/control modules. The second part, distribution, represents the mark-up and inventory carrying cost associated with a sales structure that involves a distribution network. The last part, installation, includes costs for materials (tube, fittings, solder, etc) and labour charges incurred for the assembly of all system components into a working solar system.

All the conventional systems examined fell into two basic categories, active closed loop with antifreeze as the working fluid or indirect drain-back employing water. The array of collector modules had an average total area of 5.6 m^2 (60 ft^2) per system. The nominal dimensions for the liquid flatplate collectors were generally 2134 x 914 x 102 mm (7' x 3' x 4"). All the conventional systems had a heat exchanger and at least one storage tank in addition to an electric backup tank. As well as the conventional systems, some refrigerant-charged solar domestic water heating systems were examined. The results of the survey are presented below.

2. Cost Breakdown of Conventional Solar Domestic Water Heating Systems

The following pie chart (Figure A2.1) illustrates the results for this survey of conventional Solar Domestic Water Heating Systems.

The average installed cost for a system was $4,178 (June 1982). As expected the manufacturing part of the total installed system cost was the largest (58%). Distribution costs averaged 11%. This lower than expected value was probably due to the relatively small distribution network. Most solar domestic water heating systems could be purchased straight from the manufacturer. Installation costs represented a larger than expected portion (31%) of the total installed system cost. Thus, it appears that the manufacturing and installation sections offer the greatest possibility for cost reduction to the consumer.

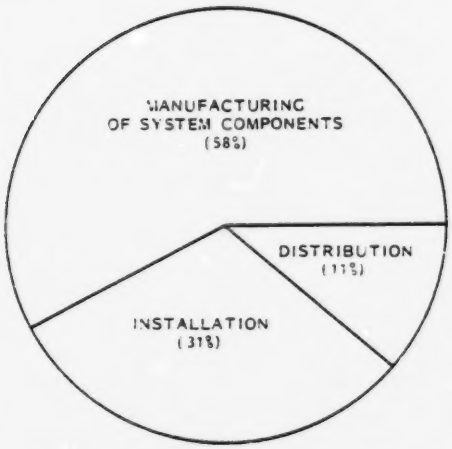

FIGURE A2.1
COST ANALYSIS OF CONVENTIONAL SYSTEM

3. Breakdown of Manufacturing Cost for Conventional Systems

Since the manufacturing cost represents the largest portion of the installed system cost, it was examined in more detail. The following pie chart (Figure A2.2) represents the findings of the study.

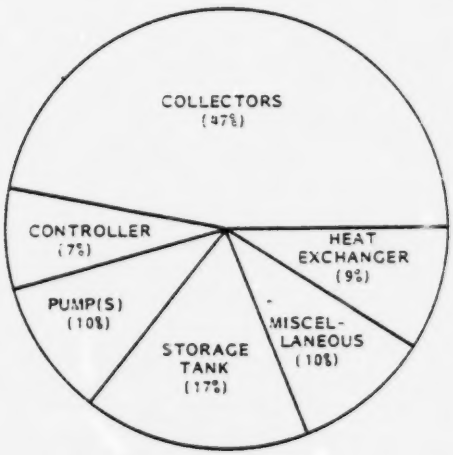

FIGURE A2.2
MANUFACTURING COSY BREAKDOWN
(Conventional System)

The collectors accounted for almost half of the manufacturing cost and may offer the greatest potential for cost reduction.

The storage tank/heat exchanger section required the second highest manufacturing cost. The manufacturing cost of the other components did not yield very much in the area of cost reduction, as these components were generally fixed in cost by the various suppliers and offered little flexibility for modifications to their design. Because of their relatively low cost, design alterations were not practical. However, for the larger cost items like collectors and storage tanks, low cost design and volume production may result in reduction of costs.

For more details on the survey results, see Appendix B1.

4. Cost Breakdown for Refrigerant-Charged Solar Domestic Water Heating Systems

In addition to the conventional solar domestic water heating systems, four refrigerant-charged systems (three active and one passive) were examined. There are currently about ten refrigerant-charged systems availabe in Canada and the United States but many of them are still under development. For this survey, the same format as the conventional systems was followed. The following pie chart (Figure A2.3) represents the results for this study.

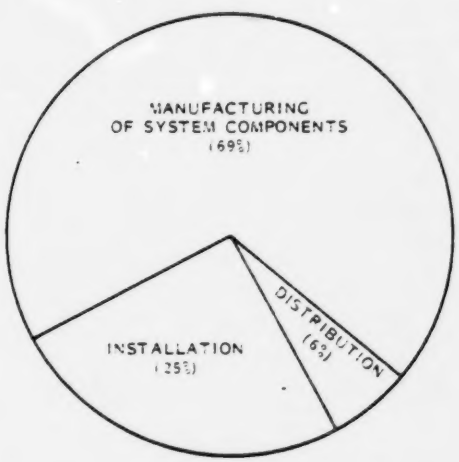

FIGURE A2.3
COST ANALYSIS OF
REFRIGERANT-CHARGED SYSTEM

The average installed cost for this type of system was $3,870 (June 1982). The manufacturing cost represented the largest portion of the installed system cost followed by the installation which accounted for one-quarter of the cost to the consumer. Similar to the conventional system survey, the distribution costs were found to be lower than expected. This is because this technology is in an early stage of development and an extensive distribution network has not yet been developed.

For the refrigerant-charged systems, the installation represented a smaller percentage of cost than in the conventional systems. This may have been due to the fact that most refrigerant-charged systems have pre-assembled modules which require less time for on-site installation. This observation is also supported by the proportionally larger percentage of manufacturing cost.

5. Breakdown of Manufacturing Cost for Refrigerant-Charged System

The manufacturing portion of the installed cost for a refrigerant-charged system was examined in detail. The following pie chart (Figure A2.4) illustrates the average cost breakdown.

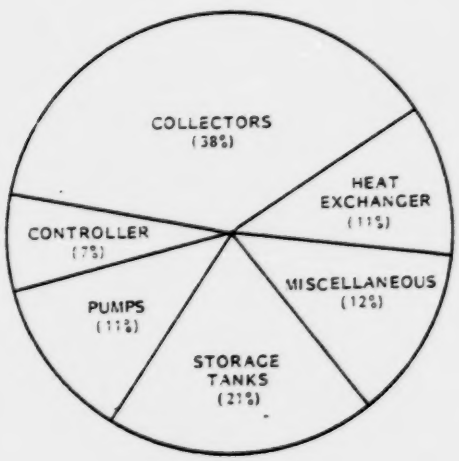

FIGURE A2.4
MANUFACTURING COST BREAKDOWN
(Refrigerant-Charged System)

The collectors accounted for the largest portion of the manufacturing cost. However, the collector for this system was found to be cheaper (cost per unit area) than that of the conventional system. This difference was probably due to the use of less expensive metals (steel and aluminum compared to copper) and the usually larger refrigerant-charged collector panel size. Thus only one or two collectors are needed for such a system compared to three or more for the conventional system. The storage tank/heat exchanger offered some potential for reducing costs but more innovative low-cost design and mass production of this major component is needed. The rest of the system components, which are relatively low cost components, offered little cost reduction.

The difference in cost to the consumer between the conventional and refrigerant-charged systems was roughly $300 in favour of the latter, which represents about 7% of the conventional solar system costs. For more details on the survey results for active refrigerant-charged systems, see Appendix B2.

APPENDIX A3

SURVEY OF MATERIALS USED FOR SOLAR DOMESTIC WATER HEATING SYSTEMS

In the preceding sections the cost breakdowns for conventional and refrigerant-charged solar domestic water heating systems were examined. The results were used to identify areas that would offer the greatest potential for cost reduction.

In this section, both standard system components and materials for the manufacture of collectors were investigated. Their cost and feasibility of application were examined along with the potential for cost reduction.

1. Results of Survey for Conventional Collectors

The liquid flatplate collector is unique to the solar industry in that it is the only component of the solar domestic water heating system that cannot be found in other industries. Storage tanks, heat exchangers, pumps, control systems, etc, are routinely used in one form or another in heating ventilation and air conditioning (HVAC) or plumbing related industries.

The materials for the construction of a collector were divided into six categories: glazing, absorber, absorber coating, thermal insulation, housing and the balance of collector which included fasteners, gaskets, etc.

A survey of the cost of these sub-components was carried out. The details of this survey are documented in Appendices C1 through C5, inclusive. A cost study on the construction of collectors was carried out in two parts. The first part consisted of using the information gathered and examining the cost of building various collector modules. The second part consisted of a similar cost study performed by some of the solar equipment manufactureres. The collector size was assumed to be 2134 x 914 x 102 mm (7' x 3' x 4"). Many criteria were used to limit the number of combinations possible in building a collector and these included the following:

a) The optical and thermal properties of the glazing and the absorber coating.

b) The availability, integrity of the material and the heat transfer capability of the absorber plate.

c) The thermal resistivity of thermal insulation materials.

d) The integrity of the collector housing.

e) The feasibility of the design and the ease of installation.

The average results of this survey are represented in the following diagrams (Figures A3.1 and A3.2). For more detailed information refer to Appendix C6.

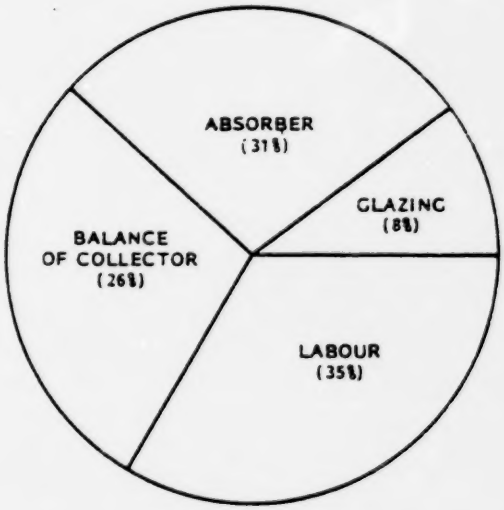

FIGURE A3.1
RESULTS FOR COST ANALYSIS
OF SOLAR COLLECTORS

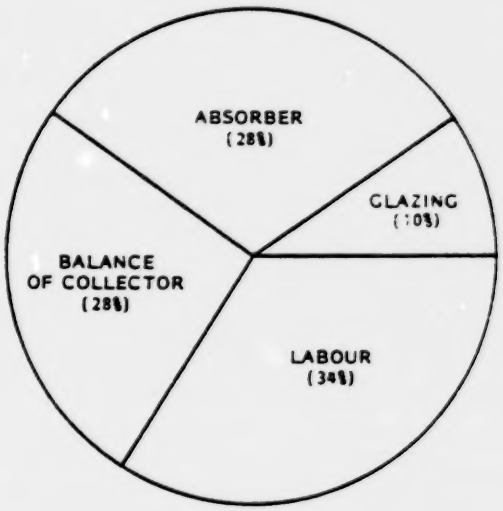

FIGURE A3.2
COST ANALYSIS OF SOLAR
COLLECTORS - MANUFACTURERS' RESULTS

In the collector cost study performed by Ontario Hydro, the unit cost for a collector ranged from $113.78 to $160.50 per square metre ($10.57/ft^2 to $14.91/ft^2) which was about the same as the costs suggested by various Canadian manufacturers. The study indicated that very little cost reduction can be achieved from the conventional solar collectors (using tempered glass glazing, roll-bond or fintube absorber and metal housing) with a low production level (less than 10,000 panels per year).

The study performed by the manufacturers indicated a somewhat reduced cost (about 10%) for the solar collectors. All examples were for a facility with an annual production capacity of less than 40,000 panels. A consulting firm (Booz, Allen and Hamilton)/1/ had performed a conventional flat plate collector cost study using a small semi-automated facility and a highly automated plant. The study indicated that for a small semi-automated facility with an annual production capacity of 50,000 to 75,000 panels, a decline of cost of about 8% is expected (from $14US/ft^2 to $12.80 US/ft^2). A highly automated plant with an annual production capacity of 150,000 to 200,000 panels could further reduce the cost by about 17% (from $12.80US/ft^2 to $10.60US/ft^2). However, at the current

annual production levels (less than 10,000 panels from one facility) there is little opportunity for cost reduction due to the continued use of labour intensive manufacturing process.

2. Survey of Unconventional Collectors/Systems

A number of companies are involved in the research and development of innovative collector designs. For example, Solaron Corporation is developing an integrated Storage Collector (ISC)/2/. This collector system requires no pumps, valves, controllers or electricity. The collector holds a body of water (horizontally) which is open to the effects of temperature extremes. This body of water is contained in a tray-like collector housing and covered with a semi-cylinder shaped glazing. Water has a high heat of fusion value and in the event of actual partial freezing, the layer of ice would provide insulation against further heat losses, thus providing some sort of natural freeze protection. It was determined that such a system can operate favourably, year round, in New England, but its use in the Canadian climate is questionable at this point. With mass production, the integrated storage collector is expected to cost about $400 US for a 1.2 m x 2.4 m configuration ($139/m^2).

Another innovation is the light-weight concrete absorber developed by Solar Energy Research Institute in the United States. The projected cost is around $330 US per square metre and is expected to have an intercept efficiency of 80%/2/.

Rubber absorbers made of EPDM (ethylene-propylene-diene-monomer) are being developed for solar applications. This material has an expected life span of 20 years and remains flexible over a wide temperature range. At the present time, the cost of this collector is about the same as for conventional collectors but the cost reduction potential is more promising/2/.

The thin-film polymeric collector developed by Brookhaven National Laboratory is extremely light-weight and suitable for low-pressure applications. The installed cost for this collector is expected to be about $54 US per square metre. This represents a reduction in cost of greater than 60%/3/.

The integral zeolite collector uses a chemical of the same name packed underneath on all copper absorber plate. This chemical expels water vapour when heated and absorbs it when cooled. In effect, the system works like a compressor capable of 10:1 compression ratio. At present the cost is quite high but developers feel that with mass production this product will become competitive/2/.

Booz, Allen and Hamilton had reported a cost of approximately $125 US* per square metre including mark-up for evacuated tube collectors at a production level of less than 10,000 units per year.

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* The costs were for 1970/1980 US dollars.

The following shows the reduction in cost as the production level increases:

Production Level	Cost/square metre including mark-up (US $)*
<20,000	118
20,000 - 150,000	97
150,000 - 500,000	70
500,000+	60

It should be mentioned that the survey on unconventional solar collectors could not lead to a firm answer of the installed cost in the foreseen future. But the preliminary results obtained illustrate that major efforts are now made toward developing new technologies and cutting down the capital and installation costs to reasonable and more acceptable market values.

3. Storage Tank/Heat Exchanger

The storage tanks are classified as either pressurized or non-pressurized. The tanks are available with or without internal heat exchangers. The cost of the heat exchanger portion of the tank is quite substantial. For example, the average cost for a pressurized 304 L (80 US gal) glass-lined tank is about $420 Cdn and about $520 when the heat exchanger is present. The stone-lined tank offers an alternative to the glass-lined tank but is more expensive and difficult to handle because of its weight. The internal heat exchanger is an integral part of the tank and when it fails, the whole tank must be replaced. An exception to the rule is the bolt-on immersible bundle type heat exchanger available for some tanks. However, this heat exchanger is quite difficult to clean and repair.

The non-pressurized tank appears to be less expensive than the pressurized tank. However, the problem of transferring heat from the non-pressurized storage water to the pressurized city water creates costs. It may be accomplished by using an external heat exchanger which is generally very expensive. This type of heat exchanger also calls for an additional circulation pump which adds more cost to the solar system. The non-pressurized tank appears less expensive than the pressurized tank but the overall cost for storage and heat transfer is about the same for either classification due to the additional labour and hardware costs. In addition, there are few non-pressurized tanks available for solar domestic water heating systems. Cost reductions could be realized if further work is done in areas of design and manufacture of a complete storage tank/heat exchanger system for solar applications specifically.

For further details on cost and availability of both standard and non-standard storage tanks, refer to Appendices C7 and C10.

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* The costs were for 1970/1980 US dollars

4. Balance of System

This section examines the remaining major components needed for a working solar water heating system.

The controller generally is a differential-temperature type and the pumps for the most part are of the centrifugal type. A proportional controller may be used but does not appear to be cost effective. These items do not offer much in the way of solar water heater cost reduction since they represent a very small portion of the total installed system cost. As with all the other components, large scale purchases can greatly reduce the individual costs for these items, but the market must warrant this.

For more detailed information on controller and pumps refer to Appendices C8 and C9 respectively.

Other materials needed for the complete picture of an installed system cost were also examined. They included: working fluids (Appendix C11), and tubing, pipe insulation, valves, fittings, etc (Appendix C12).

APPENDIX B1

CONVENTIONAL CANADIAN SOLAR DOMESTIC WATER HEATING SYSTEMS COST BREAKDOWN

Company Reference Code	Manufacture and Assembly							Distribution	Installation		Total Cost (Installed System) ($)
	Component Breakdown As A Percentage of Mfg Cost (%)						Mfg Cost ($)	Approximate Mark-up (Percentage of Total Installed Cost) (%)	Approximate Cost (Including Materials Labour & Mark-up) ($)	Percentage of Total Installed Cost (%)	
	Collector	Storage Tank	Heat Exchanger	Pump(s)	Controller	Miscellaneous					
A1	48	16	← 21 →		5	10	2225	15	1300	34	3860
A2	60	13	5	15	5	2	2000	25	1000*	29	3500
A3	50	← 32 →		5	3	10	3145	N/A	1500	32	4645
A4	63	← 25 →		5	6	1	2077	30	1200	32	3900
A5	27	← 58 →			15	0	2680	N/A	1500	36	4180
A6	41	11	N/A	14	8	26	2500	35	1240†	27	4614
A6a	36	← 19 →		12	7	26	2600	35	1240†	26	4750
A7	53	← 25 →		6	5	11	2300	13	1100*	20	3700
A8	44	← 33 →		← 23 →			2100	45	1400	28	4450

* Average cost for materials assumed to be $400

† Average installation cost used where information not available.

N/A Not Available

APPENDIX B2

REFRIGERANT CHARGED SOLAR DOMESTIC HEATER HEATING SYSTEM COST BREAKDOWN

Company Reference Code	Manufacture and Assembly							Distribution	Installation		Total Cost (Installed System) ($)
	Component Breakdown as a Percentage of Manufacturing Cost (%)						Mfg Cost ($)	Approximate Mark-up (Percentage of Total Installed Cost) (%)	Approximate Cost (Including Materials, Labour & Mark-up) ($)	Percentage of Total Installed Cost (%)	
	Collector	Storage Tank	Heat Exchanger	Pump(s)	Controller	Miscellaneous					
B1	35	19	8	13	7	18	1440	N/A	360	20	1800
B2	40	33	←	20	→	7	4387	N/A	1463	25	5850
B3	39	25	12	9	3	12	2094	30	1240	31	3970
B3a†	47	31	14	3	5	0	1721	28	1240	36	3443

† Passive system.

N/A Not available

APPENDIX C1

COLLECTOR COMPONENTS: GLAZING

Reference Code	Generic Name	Standard Dimensions (in)	†† Quantity	Unit Cost ($/ft^2)
G1	Acrylic	84x36x0.118	1000	1.23
G2	Acrylic	84x36x0.118	1000	1.19
G2a	Polycarbonate	84x36x0.125	1000	2.68
G2b**	Polycarbonate	96x48x0.220	1000	1.69
G2c	Polyester	84x38x0.005	1000	0.17
G3	Glass	84x36x0.158	1000	0.68
G3a	Glass, Tempered	84x36x0.197	1000	0.74
G4	FEP	84x36x0.001	1000	0.60
G4a	FEP	84x36x0.005	1000	2.18
G4b	Polyester U.V. Stabilized	84x36x0.005	1000	0.70
G5	Polycarbonate	84x36x0.125	1000	2.57
G6	Acrylic	96x72x0.118	1000	1.69*
G7	PVF	84x48x0.004	1000	0.56
G8	Glass	84x36x0.197	1000	1.10
G8a	Glass, Tempered	84x36x0.197	1000	1.21
G9	FRP	84x48x0.039	1000	0.67
G10	Glass, Low Iron, Tempered	84x34x0.118	420	0.99*
G11	Acrylic	84x36x0.118	1000	1.17*
G11a	Polycarbonate	84x36x0.118	1000	2.31*
G12†	Glass, Low Iron, Tempered	87x24x0.125	>50	4.93*
G13	Acrylic	84x36x0.118	1000	1.18*
G14	Glass,Tempered	84x36x0.197	1000	0.74
G14a	Glass, Low Iron, Tempered	76x34x0.197	100	2.00

Notes:
FEP - Fluorinated Ethylene Propylene
PVF - Polyvinyl Fluoride
FRP - Fibre Reinforced Polyester
* - US $'s x 1.3 → Canadian $'s
** - Double Wall Sheet, 0.060" thick per sheet
† - Glazing Assembly; includes frame, seals etc
†† - Minimum required quantity for listed unit cost.

GLAZING MATERIALS
CLASSIFICATION ACCORDING TO GENERIC NAME

Generic Name	Reference Code	Depth (in.)	Cost Per Volume ($/in^3)	Cost Per Area ($/ft^2)	Cost Per Area Average ($/ft^2)
Polyester	G 2c	0.005	0.236	0.17	0.17
	G 4b †	0.005	0.972	0.70	0.70
PVF	G 7	0.004	0.972	0.56	0.56
FEP	G 4	0.001	4.167	0.60	0.52**
	G 4a	0.005	3.028	2.18	
FRP	G 9	0.039	0.119	0.67	0.67
Glass	G 3	0.158	0.029	0.68	0.78**
	G 8	0.197	0.038	1.10	
& Tempered	G 3a	0.197	0.026	0.74	0.90**
	G 14	0.197	0.026	0.74	
	G 8a	0.197	0.042	1.21	
& Low Iron	G 10	0.118	0.058	0.99*	1.10**
	G 14a	0.197	0.070	2.00	
Acrylic	G 11	0.118	0.069	1.17*	1.29
	G 13	0.118	0.069	1.18*	
	G 2	0.118	0.070	1.19	
	G 1	0.118	0.072	1.23	
	G	0.118	0.099	1.69*	
Polycarbonate	G 11a	0.118	0.136	2.31*	2.42**
	G 5	0.125	0.143	2.57	
	G 2a	0.125	0.149	2.68	

NOTES: * US Mfg, US $'s x 1.3 → Canadian $'s
** Average cost, thickness adjusted to that of the first entry (smallest)
† Ultraviolet light-stabilized.

APPENDIX C2

COLLECTOR COMPONENTS: ABSORBER COATINGS

Reference Code	Generic Name	Survey Area (ft^2)÷	Absorptivity/ Emissivity (α/ε)	Unit Cost ($/$ft^2$)
AC1	Paint Semi-Selective	3200	0.97/0.60	0.26*
AC2	Black Chrome	25000	0.95/0.10	1.17*
AC3	Black Chrome	26000	0.95/0.10	1.15*
AC4	Paint Semi-Selective	11000	0.96/0.42	0.22
AC5	Paint	18000	N/A	0.46*
AC6	Black Chrome	740	0.93/0.10	1.95*
AC7	Paint Semi-Selective	11000	N/A	0.17*
AC8	Paint	200	0.98/N/A	0.50*
AC9	Paint Semi-Selective	200	0.93/0.52	0.39*
AC10	Paint	200	0.90/0.68	0.14*
AC11	Paint	200	0.95/0.74	0.14*
AC12	Black Chrome	24000	0.95/0.10	1.50
AC13	Paint Semi-Selective	N/A	N/A	0.38
AC14	Paint	21000	N/A	0.20*
AC15	Paint	22000	0.95/0.87	0.33*
AC16	Black Chrome	22000	0.95/0.10	1.63*

Notes:

÷ Coverage Assumed, 200 ft^2/gal

* US Mfg US $'s x 1.3 → Canadian $'s

N/A Not Available

ABSORBER COATING
CLASSIFICATION ACCORDING TO THE GENERIC NAME

Generic Name	Reference Code	Absorptivity over Emissivity (α/ε)	Unit Cost ($/ft^2)
Paint	AC 10	0.90/0.68	0.14*
	AC 11	0/95/0.74	0.14*
	AC 14	N/A	0.20*
	AC 15	0.95/0.87	0.33*
	AC 5	N/A	0.46*
	AC 8	0.98/N/A	0.50*
Semi-Selective	AC 7	N/A	0.17*
	AC 4	0.96/0.42	0.22
	AC 1	0.97/0.60	0.26*
	AC 13	N/A	0.38
	AC 9	0.93/0.52	0.39*
Average Cost For Various Paints			0.29
Black Chrome	AC 3	0.95/0.10	1.15*
	AC 2	0.95/0.10	1.17*
	AC 12	0.95/0.10	1.50
	AC 16	0.95/0.10	1.63*
	AC 6	0.95/0.10	1.95*
Average Cost For Black Chrome			1.48

NOTES: * US Mfg US $'s x 1.3 → Canadian $'s

Coating coverage assumed to be 200 ft^2 per gallon (paints)

N/A Not Available

APPENDIX C3

COLLECTOR COMPONENTS: ABSORBER

Reference Code	Generic Name	Standard Dimensions (in)	Quantity *	Unit Cost ($/ft^2)
A1	Rollbond Aluminum	36x96x3/8	1200	2.34
A2	300 ° Wrap Fintube	48x96	100	5.32
A3	Black Chrome on Copper	24x0.010xL	25000 ft^2	2.80
A4	Fintube All Copper	33x91x1-1/8	1000	7.10
A5	EPDM Matt +	48x80x1-1/2	2200 ft^2	5.60
A6	Fintube	48x78x1.0	1000	3.45
A7	Fintube All Copper	34x76x1-1/8	1000	4.65
A8	Liquid Absorber Plate Serpentine	24x48x0.375	Small Volume	10.24
A9	Finned-Tube Copper and Aluminum Plate	33x78x1-1/4	1	8.59
A10	Rollbond 24 Ga Cold Rolled Steel	24x87x3/4	51	1.92
A11	Fin-Coil Serpentine Layout	36x96x3/4	1000	3.00
A12	Fintube All Copper	34x74x3/4	1000	4.21
A13	Fintube	34x94x3/4	1000	3.78
A14	Fintube All Copper	34x74x3/4	500	3.51
A15	Cross Linked Poly-ethylene	18x600x0.630	25000 ft^2	2.81

NOTE: L is length
Ga is gauge
* minimum required quantity for the listed unit cost
+ ethylene-propylene diene-monomer

ABSORBERS
CLASSIFICATION ACCORDING TO GENERIC NAME

(With Manifolds and No Absorber Coating Unless Noted)

GENERIC NAME	REFERENCE CODE	REMARKS	UNIT COST ($/Ft^2)
ROLLBOND	A10	20 GA CRS***	1.92*
	A1	Aluminum	2.34
FINTUBE	A6	All copper	3.45*
	A14	All copper	3.51*
	A13	All copper	3.78*
	A12	All copper	4.21*
	A7	All copper	4.65*
	A2	All copper	5.32*
	A4	All copper	7.10*
AVERAGE COST FOR FINTUBE ABSORBERS			4.57
SERPENTINE**	A8	Tube; Copper, Plate; Aluminum.	10.24*
POLYETHYLENE	A15	Cross-Linked	2.81*
EPDM +++	A5	Matt	5.60
FINNED - TUBE**+	A9	Tube; Copper, Fin; Aluminum.	8.59
FINNED - COIL+	A11	As A9 only tubes are Serpentine - Layout	3.00
ABSORBER PLATE++	A15	Polyethylene	2.35*
	A5	EPDM Matt	3.37
	A3	Black chrome on Copper Sheet	2.80*
	A2	Riser & Plate	1.24*

NOTES:
* US manufacture, US $'s x 1.3 → Canadian $'s
** Retail costs, low volume purchase
*** 20 gauge, cold rolled steel
\+ Fin normal to tube axis
++ Examples of absorber without manifolds
+++ ethylene-propylene-diene-monomer

APPENDIX C4

COLLECTOR COMPONENTS: THERMAL INSULATION

Reference Code	Generic Name	Standard Dimensions (in)	Quantity** (BF)†	Unit Cost ($/BF)†
I1	Cellulose	Loose	42000	0.037
I2	Polyvinyl Chloride	96x48x1.5	4800	1.753*
I3	Polyurethane	96x48x2	20000	0.754*
I4	Cellulose	Loose	42000	0.043
I4a	Cellulose & Resin	Loose	42000	0.300
I4b	Glass, Fibre	Loose	42000	0.036
I5	Styrofoam	96x48x2	64000	0.340
I6	Glass, Fibre Board	48x24x3	3000	0.197
I7	Elastomeric	48x36x1	24000	2.042
I8	Urethane, Foil Faced	96x48x2	42000	0.503
I9	Urethane, Foam Kit	Loose	1600	0.650
I10	Glass, Cellular	24x18x2	12000	0.700
I11	Polystyrene	96x48x2	42000	0.133
I12	Polyisocyanurate, Glass Reinforced & Foil Faced	96x48x2	50000	0.465
I13	Elastomeric	48x36x1	24000	2.614
I14	Glass, Fibre	48x24x4	4000	0.085
I14a	Glass, Fibre, Foil Faced	48x24x4	4000	0.138
I15	Urethane	96x48x2	1000	0.510
I16	Mineral Fibre	Loose	42000	0.035
I17	Glass, Cellular	25x8x2	6	1.08*
I18	Isocyanurate	96x48x2	50000	0.468*
I19	Cellulose	Loose	42000	0.034
I19a	Glass, Fibre	Loose	42000	0.033
I19b	Glass, Batts	48x24x2	42000	0.046
I19c	Mineral Fibre	Loose	42000	0.035

NOTES: *US Manufacture; US $'s x 1.3 → Canadian $'s

†Board Foot (12"x12"x1")

** Minimum required quantity for the listed unit cost

THERMAL INSULATION
CLASSIFICATION ACCORDING TO THE GENERIC NAME

GENERIC NAME	REFERENCE CODE	REMARKS	UNIT COST ($/BF÷)
Glass, Fibre	I19a	Loose, R=2.7	0.033
	I4b	Loose, R=2.9	0.036
	I19b	Batts, R=3	0.046
	I14	Batts, R=3	0.085
	I6	Rigid	0.197
& Foil Faced	I14a	Semi-Rigid	0.138
Glass, Cellular	I10	Rigid, R=3.03	0.700
	I17	Rigid, R=2.8	1.080*
Urethane	I8	Foil Faced	0.503
	I15		0.510
	I9	Foam Kit, R=7	0.650
Polyurethane	I3	R=8.5	0.754*
Isocyanurate	I12	Glass Re-inforced, Foil Faced, R=8	0.465
	I18	R=7	0.468*
Styrofoam	I5	40 psi Compressive	0.340
Polyvinyl Chloride	I2	Rigid, R=7	1.753*
Polystyrene	I11	Rigid, R=3.7	0.133
Cellulose	I19	Loose	0.034
	I1	Loose, R=2.9	0.037
	I4	Loose, R=3.8	0.043
	I4a	Resin, R=4.9	0.300
Mineral Fibre	I16	Loose, R=3	0.035
	I19c	Loose, R=3	0.035
Elastomeric	I7	R=3.57	2.042
	I13	R=3.57	2.614

NOTES: * US manufacture, US $'s x 1.3 → Canadian $'s
÷ Board Foot - 12" x 12" x 1"

THERMAL INSULATION
AVERAGE UNIT COSTS

GENERIC NAME	APPROXIMATE VALUES FOR			Average Unit Cost ($/BF÷)
	R-Value ($hr \cdot ft^2/BTU$)	Temperature (°F)	Density (lbs/ft^3)	
Glass, Fibre, Loose	2.8	N/A	1.0	0.035
Glass, Fibre, Batts	3.0	N/A	N/A	0.067
Glass, Fibre, Rigid	N/A	N/A	3.0	0.197
Glass, Fibre, Foil Faced	N/A	N/A	N/A	0.138
Glass, Cellular	2.9	900	8.5	0.890
Urethane	7.4	217	2.0	0.604
Isocyanurate	7.5	237	2.0	0.467
Styrofoam	N/A	165	2.2	0.340
Polyvinyl Chloride	7.0	200	3.0	1.753
Polystyrene	3.7	180	1.0	0.133
Cellulose, Loose	3.4	350/800	2.6	0.038
Cellulose, Resin	4.9	180	4.8	0.300
Mineral Fibre	3.0	1200	2.0	0.035
Elastomeric	3.6	180	4.5/8.5	2.328

÷Board Foot - 12" x 12" x 1"

APPENDIX C5

COLLECTOR COMPONENTS: HOUSING

Reference Code	Material	Standard Dimensions (in)	*** Quantity	Unit Cost ($/Ft^2)
H1	Steel, Galv	84x36x4	1000	1.86
H2	Aluminum Extrusion	84x36x4	1000	2.81++
H3	Fibreglass & Epoxy Mould	84x36x4	1000	2.76
H4	Fibreglass & Epoxy Mould	84x36x4	1000	2.33
H5	Fibreglass & Epoxy Mould	84x36x4	1000	6.33
H6	Fibreglass & Epoxy Mould	84x36x4	1000	5.48
H7	Polyethylene Extruxion	84x36x4	1000	1.48++
H8	Aluminum Extrusion	84x36x4	48	2.65++
H9	Polyethylene Rotational Moulding	84x36x4	500	2.86
H10	Cold Rolled Steel	96x36x20 Ga+	1250	0.44**
	Cold Rolled Steel	96x36x16 Ga+	1250	0.74**
H10a	Steel, Galv	96x36x20 Ga+	1250	0.62**
	Steel, Galv	96x36x16 Ga+	1250	0.93**
H10b	Aluminum Utility Grade	96x36x20 Ga+	1250	0.67**
	Aluminum Utility Grade	96x36x16 Ga+	1250	1.06**
H11	Polyethylene Vacuum Forming	84x36x4	1000	2.38

Notes:
- * U.S. Mfg-U.S. $'s x 1.3 → Canadian $'s
- ** For back plates
- *** Minimum required quantity for the listed unit cost
- \+ Gauge
- ++ Back plate included in unit cost
  20 Ga Aluminum ($14.07 added) See H10b

HOUSING MATERIALS

Classification According To the Materials

Material	Remarks	Reference Code	Unit Cost ($/Ft^2)
Polyethylene	Extrusion & Metal Plate	H7	1.48+
	Vacuum Forming	H11	2.38
	Rotational Moulding	H9	2.86
Average Cost for Polyethylene Housing			2.24
Glass, Fibre & Resin	Mould Formed	H4	2.33
	Mould Formed	H3	2.76
	Mould Formed	H6	5.48
	Mould Formed	H5	6.33
Average Cost for Fibreglass Housing			4.23
Aluminum	Extrusion & Aluminum Back Plate	H8	2.65*+
		H2	2.81+
Steel, Galv	Brake Formed	H1	1.86
Housing Materials (For Backplates)			
Sheet Metal	Cold Rolled Steel 20 Ga	H10	0.44
	16 Ga		0.74
	Galvanized 20 Ga	H10a	0.62
	16 Ga		0.93
	Aluminum 20 Ga	H10B	0.67
	(Utility Grade) 16 Ga		1.06

Notes: * U.S. Mfg., U.S. $'s x 1.3 → Canadian $'s

\+ Back Plate added, use 20 Ga Aluminum

APPENDIX C6

COLLECTOR COST STUDY

Component	Collector Example							
	I		II		III		IV	
	Material	Cost($)	Material	Cost($)	Material	Cost($)	Material	Cost($)
Glazing	Double	22	Single	22	Double	22	Single	22
Absorber Coating	Paint	6	Selective	29	Paint	6	Selective	29
Absorber	Rollbond	45	Rollbond	45	Fintube	88	Fintube	88
Insulation	Loose F	3	Rigid F	9	Loose F	3	Rigid F	9
Housing	Steel	39	Aluminum	56	Steel	39	Aluminum	56
Miscellaneous		12		16		16		20
Material Cost		127		177		174		224
Labour†		95		89		95		89
Total Cost (3' x 7')		222		266		269		313
Unit Cost ($/ft^2)		10.57		12.67		12.81		14.91

Note: Examples represent extremes for two basic design proposals (capable of withstanding temperatures in excess of 350°F and normal water line pressures)

For explanations see "Notes on Collector Cost Studies" page

COLLECTOR COST STUDY

(Prepared by Manufacturers)

Component	Collector Example							
	A		B		C		D††	
	Material	Cost($)	Material	Cost($)	Material	Cost($)	Material	Cost($)
Glazing	Single*	26	Single	20	Single	20	Single	21
Absorber Coating	Selective	33	Paint**	11	Paint	11	Paint	6
Absorber	Fintube	48	Fintube***	39	Rollbond	40	Rollbond	59
Insulation	Rigid F	4	Loose F	3	Rigid F	4	Rigid U	23
Housing	Aluminum	74	Aluminum†	60	Plastic	15	Aluminum Extrusion Fabrication	85
Miscellaneous		17		12		8		
Material Cost		202		145		98	Assembly Profit & Shipping	
Labour		80		72		68		
Total Cost (3'x8')		282		217		166	(3' x 7')	194
Unit Cost ($/ft^2)		11.75		9.04		6.92		9.24

* Crystal clear, low iron tempered
** Selective paint
*** Without header
† Galvanized steel bottom
†† Represented cost to Hydro for the extrusion, fabrication and assembly of the collector. The end cost includes profit and shipping charges.

For explanations, see "Notes on Collector Cost Studies" page 37

INNOVATIVE COLLECTOR COST STUDY

COMPONENTS	COLLECTION EXAMPLES (4'X8')			
	E		F	
	MATERIAL	COST($)	MATERIAL	COST($)
Glazing	PVF	13	PAN	3
Absorber coating	PAINT*	1	PAINT*	1
Absorber	LAMINATE	24	LAMINATE	6
Insulation	RIGID FOAM	5	RIGID FOAM	5
Housing	GALV. STEEL	4	GALV. STEEL	4
Miscellaneous		7		3
Material Cost		54		22
Labour		2		2
Total Cost		56		24
Unit Cost ($/ft^2)		1.75		0.75

* Selective

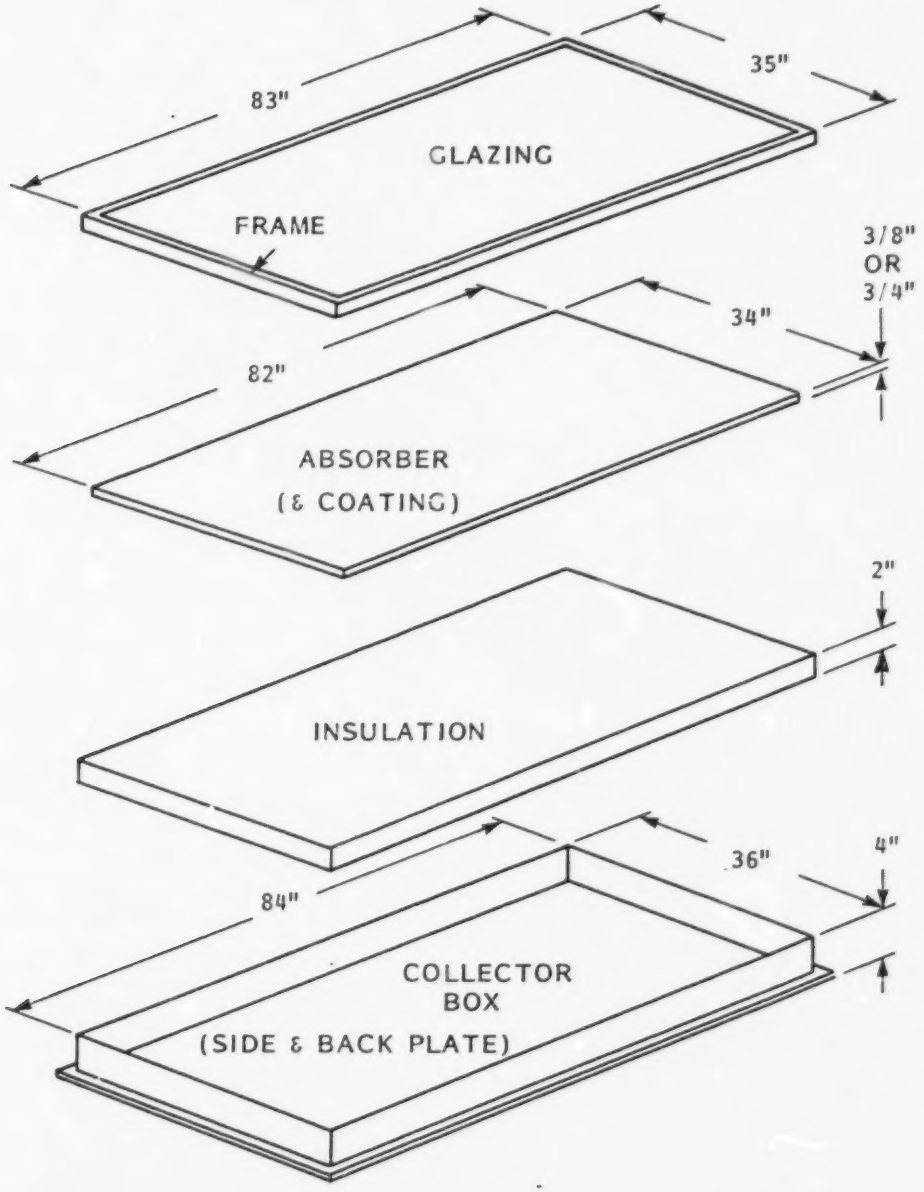
PVF - polyvinyl fluoride
PAN - poly acrylanitride
LAMINATE - two sheets of aluminum foil (0.002") outer.
two sheets of FEP or PAN (0.001") inner.

These collector examples are in the development stage as of 1981. Inflation for the year is assumed to be 12%. As well U.S. $'s x 1.3 produce Canadian dollars due to the exchange rate.

NOTES ON COLLECTOR COST STUDIES

Glazing	:	single; low iron, tempered glass unless noted, double; fluorinated ethylene propylene (FEP) for inner glazing, polyvinyl fluoride (PVF) for outer glazing.
Absorber coating	:	paint; at best semi-selective unless noted selective; black chrome
Absorber	:	rollbond; aluminum, fintube; copper, manifolds included unless noted.
Insulation	:	loose F; mineral or glass fibre, rigid F; either fibre and, with binder therefore semi-rigid, rigid U; urethane, rigid. In order to maintain a wall R-value of at least six, isocyanurate was used about the perimeter (inside) of the housing frame (1" thick and 1-1/2" high).
Housing	:	steel; brake formed galvanized steel, aluminum; extruded frame plus back plate.
Miscellaneous	:	includes hardware, gaskets, etc (taken at 10% material cost for Hydro study).
Labour	:	taken at 50% material cost for Hydro study.
Costs	:	sub-component cost derived from average unit costs for the Hydro study. All sub-component costs are rounded to the nearest dollar with the exception of collector plan view area unit cost ($/ft^2).

STANDARD COLLECTOR (LIQUID, FLAT PLATE TYPE)



NORMAL DIMENSIONS 84" X 36" X 4"

COLLECTOR COST STUDY

SUB-COMPONENTS AS A PERCENTAGE OF MANUFACTURING COST

Sub-Component	Collector Examples								
	I	II	III	IV	AVG	A	B	C	AVG
Glazing	10	8	8	7	8	9	9	12	10
Absorber Coating	3	11	2	9	6	12	5	7	8
Absorber	20	17	33	28	25	17	18	24	20
Insulation	2	3	1	3	2	1	1	2	1
Housing	18	21	15	18	18	26	28	9	21
Miscellaneous	5	6	6	6	6	6	6	5	6
Labour	43	34	35	29	35	29	33	41	34
Total (%)	100	100	100	100	100	100	100	100	100

APPENDIX C7

HEAT EXCHANGERS*(Liquid to Liquid)

Reference Code	Generic Name	Material	Surface Area (Ft^2)	Item Cost ($)	Cost Per Ft^2
Hx1**	Spiral Plate	Stainless Steel	1.80	319.80	177.67
Hx1a**	Spiral Plate	Stainless Steel	7.85	757.90	96.55
Hx2	Plate Heat Exchanger	Stainless Steel	N/A	N/A	39.00
Hx4	Immersed Coil Coaxial	Copper	13.5	150.00	11.07
Hx5**	Counterflow Coaxial	Copper	2.6	443.30	170.50
Hx5a**	Counterflow	Copper	10.4	1470.30	143.00
Hx6†	Immersed Coil	Bronze	7.85	161.00	20.51
Hx6a†	Immersed Coil	Bronze/ Copper	11.78	230.00	19.52
Hx7	Coil in Shell	Steel	6.03	93.60	15.52
Hx8	Immersed Bundle	Copper	10.0	125.50	12.50
Hx8a††	Immersed Bundle	Copper	10.0	162.50	16.25
Hx9	Coil in Shell	Copper/ Steel	4.7	169.00	35.96
Hx9a†	Immersed Coil	Copper	3.9	69.00	17.69
Average Unit Cost (Standard)					20.86
Average Unit Cost (High Effectiveness,**)					146.93
Alternatives *					
Hx3	Immersed Coil	Polybutylene	N/A	N/A	1.51
Hx3a	Immersed Coil	Polybutylene	N/A	N/A	1.93

Notes: * All U.S. manufacturers except for the alternatives
U.S. $'s x 1.3 → Canadian $'s
** High Effectiveness Heat Exchangers
† Finned Tube, Surface Area claimed to be 2.5 times nominal
†† Double Wall
N/A Not Available

APPENDIX C8

CONTROLLERS (Differential Temperature)

Reference Code	Temperature		Item Cost Based On	
	On (F°)	Off (F°)	One Unit ($)	>25 Units ($)
CR1	13	4		60.00
CR2	10	5	89.70*	
CR3	16	3	100.75*	
CR4	17	6		55.55*
CR5	5-20	2.5		58.50*
CR6	8	3		55.70*
CR7	20	3.5		85.50
CR8	15	5	140.00*	
CR9	20	4	94.50*	
CR10	4.5	<4.5	92.95*	
CR11	0-9	2	65.00*	
CR12	13.5	5.4	97.50*	
Average Cost			97.20	63.05

NOTES: *US Manufacture; US $'s x 1.3 → Canadian $'s

Generally the sensors (included in costs) are of the thermistor type (10 kΩ @ 77°F)

Proportional controllers were not considered due to the relatively high cost

APPENDIX C9

PUMPS (CENTRIFUGAL CIRCULATORS)

Reference Code	Maximum Rating Head (ft)	Maximum Rating Flow (GPM)	Material	Cost ($)
P1**	10	0.6	Bronze	94.80
P2**	3.5	3.5	Plastic	91.00*
P3	14	21	Cast Iron	150.00
P3a	21	29	Cast Iron	217.00
P4	3.2	5.2	Brass	78.00*
P4a	12	6.5	Brass	78.00*
P5 ÷	@100 psi	1	Brass	134.50*
P6	20	2	Plastic	94.30*
P7÷÷	11	22	Cast Iron	171.00
P7a÷÷	27	10	Bronze	257.00
P7b÷÷	27	10	Cast Iron	212.50
Average (individual) Unit Cost				143.54
P3	14	21	Cast Iron	63.75
P3a	21	29	Cast Iron	92.23
P7	11	22	Cast Iron	71.50
P7a	27	10	Bronze	123.00
P7b	27	10	Cast Iron	99.50
Average (>250 items) Unit Cost				90.00

Notes: * US Mfg, US $ x 1.3→Canadian $

** Magnetic Coupled(drive)

÷ Rotary Vane Pump (also suitable for refrigerant-charged systems)

÷÷ Isolation (Bronze Ball) Valves included in costs

APPENDIX C10
STORAGE TANKS AND HEAT EXCHANGER

COMPANY REFERENCE CODE	TANK		HEAT EXCHANGER		UNIT COST ($/ITEM)
	LINING	VOLUME (U.S. GAL)	SURFACE AREA (FT^2)	MATERIAL	
STHX 1***	Glass	80	21	Copper	516.10*
STHX 2	Stone	80	15	Copper	525.00
STHX 3***	None	80	20	Copper**	800.00
STHX 4	Stone	80	15	Copper	748.00*
STHX 4a	Stone	120	20	Copper	936.00*
STHX 5****	Glass	82	N/A	Copper	508.30*
STHX 5a****	Glass	120	N/A	Copper	651.30*
STHX 6	Glass	80	10	Copper	522.00*
STHX 7	Stone	80	20	Copper	456.30*
STHX 7a	Stone	120	40	Copper	649.35*
STHX 2a	Stone	120	20	Copper	725.00

Double wall heat exchangers are available (same surface area) for the following:

STHX 6 Unit Cost Increase of 7%
STHX 1 Unit Cost Increase of 18%
STHX 7 & 7a Unit Cost Increase of 18% & 29%.

* U.S. Mfg., U.S. $'s x 1.3 → Canadian $'s
** Tube not finned, all others are.
*** Double wall, preinsulated, polyethylene tank
**** Truckload Quantity, approximately 30 tanks

STORAGE TANKS

COMPANY REFERENCE CODE	TANK		REMARKS	UNIT COST ($/ITEM)
	LINING	VOLUME (U.S.GAL)		
ST1	Glass	40	Std Electric	155.00
ST1a	Glass	60	Water Heater	225.00
ST2	Glass	60	Modified to Accept Heat	200.00
ST3	Glass	60	Exchanger.	220.20
ST3a	Glass	100		425.00
ST4	Glass	82	Additional Ports	405.60*
ST4a	Glass	120	(Potable Water)	487.50*
ST6	Glass	66	Std Electric	461.50*
ST6a	Glass	80	Accepts HX	396.50*
ST7	Glass	66	Additional Ports	406.90*
ST7a	Glass	80	for Potable Water	468.00*
ST7b	Glass	120		664.30*

* U.S. Mfg., U.S. $'s x 1.3 → Canadian $'s
All costs are based on less than truck load quantities (approximately 30).

TANKS (NON STANDARD)

COMPANY REFERENCE CODE	VESSEL			LINING	UNIT COST ($/ITEM)
	TYPE	MATERIAL	VOLUME (IMP GAL)		
V1	Round	Polyethylene	60	None	123.90
V1a	Round	Polyethylene	100	None	229.95
V1b	Round	Polyethylene	150	None	330.75
V1c	Liner	Polyethylene	45	None	43.05
V2	Drum	Polyethylene	45	None	70.00
V3**	Drum	Steel	45	Food Grade	10.00
V4	Drum	Steel	45	Baked On	27.50÷
V4a	Drum	Steel	45	None	24.30÷
V4b	Tank	Steel	100	Glass	240.00
V5++	Round	Stainless	90(U.S.)	None	500.50*
V5a++	Round	Steel	110(U.S.)	None	565.50
V5b	Rect	(304)	110(U.S.)	None	513.50*
V6	Drum	Steel	45	Food Grade Baked On	45.00÷
V6a	Lining	Polyethylene	45	15 mil	2.50
V6b	Drum	Polyethylene	45	None	30.00÷

Savings could be realized for the following;

V2 @ 100 + units, less 55%
V5 @ 50 + units, less 40%
V5a @ 50 + units, less 33%
V5b @ 50 + units, less 25%

* U.S. Manufacturer, U.S. $'s x 1.3→ Canadian $'s
** Used steel drum

÷ Costs based on 100+ units
++ Only vessel that can be pressurized

STORAGE TANK AVERAGE UNIT COST

COMPANY REFERENCE CODE	LINING	VOLUME (U.S. GAL)	UNIT COST ($/ITEM)	COST PER VOLUME ($/U.S. GAL)
STHX 1	Glass	80	516.10	6.45
STHX 6	Glass	80	522.00	6.53
STHX 5	Glass	82	508.30	6.20
AVERAGE COSTS (INTERNAL HX)			515.43	6.39
STHX 2	Stone	80	525.00	6.56
STHX 4	Stone	80	748.00	9.35
STHX 7	Stone	80	456.30	5.70
AVERAGE COSTS (INTERNAL HX)			576.43	7.21
STHX 2a	Stone	120	725.00	6.04
STHX 4a	Stone	120	936.00	7.80
STHX 7a	Stone	120	649.35	5.41
AVERAGE COSTS (INTERNAL HX)			770.12	6.42
STHX 5a	Glass	120	651.30	5.43
STHX 3	None	80	800.00	10.00
ST 1	Glass	40	155.00	3.88
ST 1a	Glass	60	225.00	3.75
ST 2	Glass	60	200.00	3.33
ST 3	Glass	60	220.00	3.67
ST 6	Glass	66	461.50	6.99
ST 7	Glass	66	406.90	6.17
AVERAGE COST (JUST TANK)			278.07	4.63
ST 4	Glass	82	405.60	4.95
ST 6a	Glass	80	396.50	4.96
ST 7a	Glass	80	468.00	5.85
AVERAGE COST (JUST TANK)			423.37	5.25
ST 3a	Glass	100	425.00	4.25
ST 4a	Glass	120	487.00	4.06
ST 7b	Glass	120	664.30	5.54
AVERAGE COST (JUST TANK)			525.60	4.62

APPENDIX C11

WORKING FLUIDS

Ref Code	Generic Name	Specific Heat (BTU/ LB-F°)	Specific Gravity	Temperature Range (°F)	Cost per Gallon ($)	Cost per Pound ($)
W7a	Synthetic Hydrocarbon	0.47	0.87	0 to 600	6.24	0.86
W8	Propy.Gly.Sol'n	0.81	1.03	-55 to 228	6.50	0.76
W1	Synthetic Hydrocarbon	0.55	0.81	-90* to 325*	8.02	1.19
W2	Propy.Gly.Sol'n	0.87	1.05	-100* to 225*	8.45	0.97
W9	Propy.Gly.Sol'n	0.82	1.05	-55 to 250	13.00	1.49
W5	Synthetic Hydrocarbon	0.57	0.84	-5 to 350	14.30	2.04
W5a	Hydrocarbon	0.54	0.80	-65 to 350	19.50	2.93
W7	Ester Based	0.48	0.91	-50 to 425	17.50	2.31
W1a	Synthetic Hydrocarbon	0.55	0.83	-85* to 440*	12.70	1.84
W3	Silicone Based	0.37	0.94	-50 to 400	28.58	3.65
Average Cost for Synthetic Oils (7 items)					15.26	2.12
Average Cost for Propylene Glycol Solutions (3 items)					9.32	1.07

WORKING FLUIDS

REFRIGERANT

Ref Code	Refrig Number	Specific Heat (BTU/LB-F°) Liquid	Vapour	FP (°F)	BP (°F)	Cost per Pound ($)
W6	11	0.21	0.14	-168	74.9	4.88
W4	11					3.71
W6a	12	0.24	0.15	-252	-21.6	4.17
W4a	12					3.98
W6b	22	0.31	0.16	-256	-41.4	6.37
W4b	22					5.87
W6c	113	0.22	0.15	-31	117.6	6.55
W4c	113					4.92
W6d	114	0.25	0.17	-137	38.8	7.30
W4d	114					
W4e	717	1.10	0.50	-107.9	-28.0	2.24

APPENDIX C12

INSTALLATION HARDWARE
PIPE AND TUBING

Reference Code	Material	Type	Nominal Length (ft)	Nominal Diameter (in)	Unit Cost ($/ft)
P1	Copper	L	12	0.50	0.71†
	Copper	L	12	0.75	1.29
P2	Copper	L	12	0.50	0.67
	Copper	L	12	0.75	1.00
P3	Copper	L	12	0.50	1.12†
	Copper	L	12	0.75	1.77
P2a**	Copper, flexible	L	60	0.50	0.83
	Copper, flexible	L	60	0.75	1.35
P2b	Copper, flexible	K	66	0.75	1.80
P3a**	Copper, flexible	L	60	0.50	1.23†
	Copper, flexible	L	60	0.75	1.95
P3b	Copper, flexible	K	66	0.50	1.48†
	Copper, flexible	K	66	0.75	2.73
P1a*	Steel, galvanized	N/A	22	0.50	1.13†
P1b	CPVC	N/A	10	0.50	0.45†
	CPVC	N/A	10	0.75	0.70
P2c***	Polyethylene	N/A	100	0.50	0.13
	Polyethylene	N/A	100	0.75	0.18
P2d††	ABS	N/A	10	1.25	0.63
P4	Polybutylene	N/A	1000	0.50	0.27
P4a	Polybutylene	N/A	500	0.75	0.41

* Schedule 40 pipe

** Indoor use recommended

*** Heavy duty, cold water only

† List price less 40% for purchases of 1000 lengths

†† Generally used for drainage

N/A Not Available

INSTALLATION HARDWARE
PIPE INSULATION
(For 3/4" Dia Copper Tube)

Reference Code	Generic Name	Jacket Material	Wall Thickness (in)	Unit Cost ($/ft)
PI1	Glass fibre, rigid	N/A	1.0	1.92
PI1a †	Glass fibre, semi-rigid	Aluminum foil	0.5	∿ 0.11
PI3	Glass fibre, rigid	Kraft Paper	1.0	2.16
	Glass fibre, rigid	Kraft Paper	2.0	6.80
PI4	Elastomeric	N/A	0.75	1.44
PI5	Mineral fibre	N/A	1.0	2.29
	Mineral fibre	N/A	2.0	6.40
PI6	Elastomeric	N/A	0.75	1.62
PI7	Isocyanurate	PVC	1.5	2.73*
PI7a	Glass fibre, semi-rigid	Aluminum foil	0.75	1.14*
PI7b	Elastomeric	N/A	0.75	1.01*
PI8**	Isocyanurate	ASJ	1.0	0.88*
	Isocyanurate	ASJ	1.5	1.56*
Insulation and Copper Tube (0.75" Dia)				
PI7c	Isocyanurate	PVC	0.88	4.16*
PI2	Isocyanurate	PVC	1.0	3.97*
	Isocyanurate	PVC	1.5	4.34*
PI8a**	Isocyanurate	ASJ	1.0	3.92*

Discounts for the following are available - **
PI1 less ∿39% PI3 less ∿40% PI5 less ∿53%

PVC Jacket (J1): 0.010" x 600 ft^2 @ $0.23/$ft^2$
0.015" x 450 ft^2 @ $0.35/$ft^2$

* US Mfg, US $'s x 1.3 → Canadian $'s
** Based on 150,000 ft of product
Product sold in roll form (6" x 0.5" x 1200",
† foil face @ 0.001" thickness)
N/A Not Available

INSTALLATION HARDWARE
MISCELLANEOUS PLUMBING ITEMS

VALVES

Reference Code	Remarks	Cost Per Item ($) For Nominal Size 1/2"	3/4"
M1	Gate Type, Sweat Connection	4.49	5.99*
M2		5.72*	6.82*
M4		8.24	10.37
M2a	Globe Type, Sweat Connection	9.62*	13.39*
M4a		7.52	10.08
M2b	Swing check type, sweat and thread connections	16.12*	17.29*
M2c		15.34*	16.77*
M2b †		12.35*	17.23*
M4b		8.63	11.92
M1a		5.99	7.79
M3a ††	Isolation/flange combination	N/A	6.50

AIR REMOVAL AND EXPANSION TANKS, ETC

Reference Code	Remarks	Cost per Item ($)
M1c	Expansion Tank - 1.7 Imp Gal	39.95
	(Butyl Diaphram)-3.8 Imp Gal	54.95
M2g	Expansion Tank (75 psi, 240°F)	32.00
M3 †††	Module (Air & Pressure Control)	106.00
M2e	Combination Airvent/vacuum breaker	20.15*
M2f	Auto air vent	9.10*
M2h	Air Purger	12.50*
M1b	Combination Strainer/Foot Valve (ABS/Brass / Bronze/Brass)	5.99
		7.79

* US Mfg, US $'s x 1.3 → Canadian $'s
† Vertical orientation
†† Price for one, generally sold in sets of two
††† The module includes expansion tank, air vent and purger. A 50% discount is expected for quantity greater than 250.
N/A Not Available

INSTALLATION HARDWARE
FITTINGS FOR REFRIGERANT CHARGED SYSTEMS

Reference Code	Description	Cost* ($)
R1	5/8" x 5/8", Solder x Solder, Couplings	0.40
R2		0.36
R1a	7/8" x 7/8", Solder x Solder, Couplings	0.78
R2a		0.70
R1b	5/8" x 5/8", Solder x Solder, Union	5.46
R2b		6.12
R1c	7/8" x 7/8", Solder x Solder, Union	7.32
R2c		8.20
R1d	5/8" x 3/4", Solder x M.P.T., Adapter	2.76
R2d		3.10
R1e	7/8" x 3/4", Solder x M.P.T. Adapter	1.98
R2e		N/A
R1f	5/8" x 3/4", Solder x F.P.T., Adapter	3.42
R2f		3.86
R1g	7/8" x 3/4", Solder x F.P.T., Adapter	8.86
R2g		2.48
R1h	5/8" x 5/8", Solder x Solder, 90° Elbow	0.42
R2h		0.46
R1i	7/8" x 7/8", Solder x Solder, 90° Elbow	0.96
R2i		1.08
R1j	5/8" x 5/8", Solder x Solder, 45° Elbow	0.90
R2j		1.00
R1K	7/8" x 7/8", Solder x Solder, 45° Elbow	1.62
R2k		1.80
R1L	5/8" x 5/8", Solder x F. Flare	4.84
R2L		N/A
R1m	5/8" x 5/8", Solder x Flare	3.96
R2m		5.50
R1n	Flare Gasket, Copper 5/8" (B2-10)	0.48
R2n		1.10
R10	5/8" Flare Nut (Short)	1.42
R20		2.46

N/A - Not Available

VALVES FOR REFRIGERANT CHARGED SYSTEMS

Reference Code	Description	Cost* ($)
R1p	5/8" Ball Valve	55.68
R2p		N/A
R1g	5/8" Diaphragm	43.28
R2g	Two-Way Line Valve	41.52
R1r	5/8" Std. Check Valve	36.40
R2r	Extended Ends (Liquid)	39.12
R1s	3/8" Needle Valve	9.46
R2s	Flared Tube to M.P.T.	21.02
R1t	3/8" Pressure Relief	58.48
R2t	Valve (N.F.T., in.)	48.18

TUBING FOR REFRIGERANT CHARGED SYSTEM

Reference Code	Description	Cost* ($)
R1u	5/8", 12 ft Lengths	17.00
R2u	Type L, Copper	16.58
R1v	7/8", 12 ft Lengths	26.00
R2v	Type L Copper	24.68
R1w	5/8", 50 ft Coils	66.60
R2w	Soft Copper	64.48
R1x	7/8", 50 ft Coils	90.48
R2x	Soft Copper	87.52
R1y	3/8", 50 ft Coils	37.10
R1y	Soft Aluminum	21.76

Liquid Indicator

R1z	5/8", ODS	25.65
R2z	50 Series	15.84

*List prices (1982) discounts of as much as 40%

for large purchases.

All fractions represent outside diameters or nominal pipe thread sizes

N/A Not Available

APPENDIX D1

SYSTEM TYPE: REFRIGERANT CHARGED CLOSED LOOP, TWO TANK

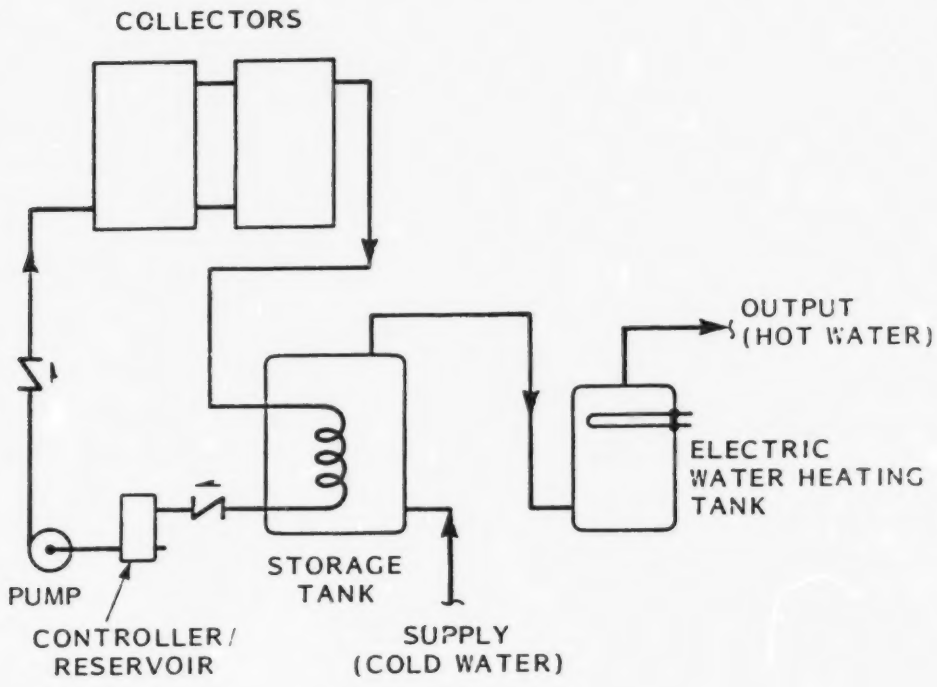


FIGURE D1

SYSTEM COMPONENT LIST

Item	Description	Ref No	Cost
Storage Tank	80 Gal (US), glass lined double wall internal Hx	STHX 6	559
Heat Exchanger	Above		
Drain Back Tank	None		
Pump	Rotary Vane Pump and Electric Motor	P5	135
Collectors	Rollbond (aluminum) minimum of two needed	Type I	444
Controller	Float switch, relay and housing (designed and built by Ontario Hydro)	N/A	127
Working Fluid	45 lbs of R-11 @ $3.71/lb (4.6 L/collector and 4.3 L/ 50 ft of tube)	W4	167
TOTAL COST			$1432

APPENDIX D2

SYSTEM TYPE: CLOSED LOOP, TWO TANK

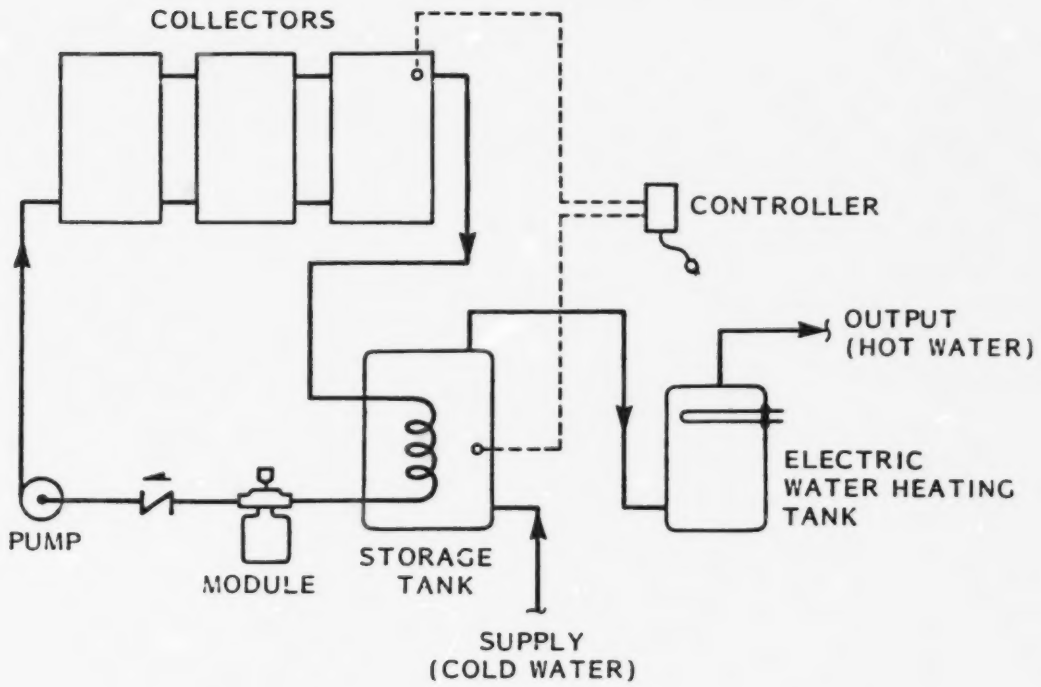


FIGURE D2

SYSTEM COMPONENT LIST

ITEM	DESCRIPTION	REF NO	COST
STORAGE TANK	80 GAL (US), GLASS LINED TANK DOUBLE WALL HEAT EXCHANGER	STHX 6	559
HEAT EXCHANGER	ABOVE	-	-
MODULE	AIR VENT, PURGER AND EXPANSION TANK MODULE	M3	53
PUMP(S)	(LARGE PURCHASE PRICE)	N/A	90*
COLLECTORS	FINTUBE (COPPER) 3 NEEDED	TYPE III	807
CONTROLLER	(LARGE PURCHASE PRICE)	N/A	63*
WORKING FLUID	PROPYLENE GLYCOL SOLUTION TOTAL VOLUME @ 6 GAL (US)	-	56*
TOTAL COST			$1628

* AVERAGE COST

APPENDIX D3

SYSTEM TYPE: DRAIN BACK, TWO TANK

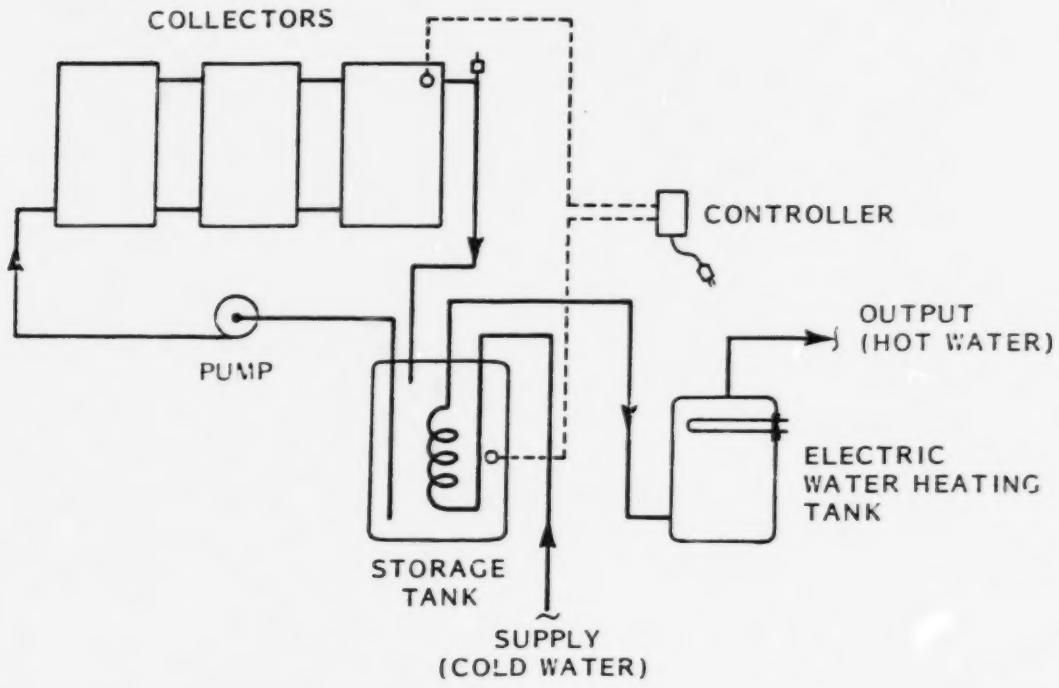


FIGURE D3

SYSTEM COMPONENT LIST

Item	Description	Ref No	Cost
Storage Tank	100 Gal polybutylene tank, 4" of fibreglass insulation, jacket and 150' of 1/2" dia coiled uppper tube	Vla	588**
Heat Exchanger	Above		
Drain Back Tank	(as storage)		
Pump	(large purchase price)	N/A	90*
Collectors	Fintube (copper) 3 needed	Type III	807
Controller	(large purchase price)	N/A	63*
Working Fluid	Potable water		
TOTAL COST			$1548

* Average cost
** Labour factor at 1.5 times material costs

APPENDIX D4
COST COMPARISON OF VARIOUS SYSTEM TYPES EMPLOYING EXAMINED COLLECTOR DESIGNS

REFRIGERANT-CHARGED CLOSED LOOP, TWO TANK (FIG D-1)

COSTS ($)	COLLECTOR EXAMPLES			
	I	II	C	D
COLLECTOR*	444	532	332	388
BALANCE OF SYSTEM	988	988	988	988
COMPONENT TOTAL	1432	1520	1320	1376
INSTALLED TOTAL ***	2572	2712	2442	2518

CLOSED LOOP, TWO TANK (FIG D-2)

COSTS ($)	COLLECTOR EXAMPLES			
	III	IV	A	B
COLLECTOR **	807	939	846	651
BALANCE OF SYSTEM	821	821	821	821
COMPONENT TOTAL	1628	1806	1667	1472
INSTALLED TOTAL***	2849	3060	2910	2647

DRAIN-BACK, TWO TANK (FIG D-3)

COSTS ($)	COLLECTOR EXAMPLES					
	III	IV	A	B	E	F
COLLECTOR**	807	939	846	651	112	48
BALANCE OF SYSTEM	741	741	741	741	741	741
COMPONENT TOTAL	1548	1680	1587	1392	853	789
INSTALLED TOTAL***	2741	2952	2802	2539	1812	1725

* Aperture area between 42 and 48 sq ft (2 collectors)

** Aperture area between 63 and 72 sq ft (3 collectors)

*** Low end of range based on average plumbing hardware cost, labour on a 35% mark-up on component total for overhead and budget.

APPENDIX E
DETAILS FOR INSTALLATIONS OF CONVENTIONAL SOLAR DOMESTIC WATER HEATER SYSTEMS AT A TYPICAL RESIDENCE

Lines

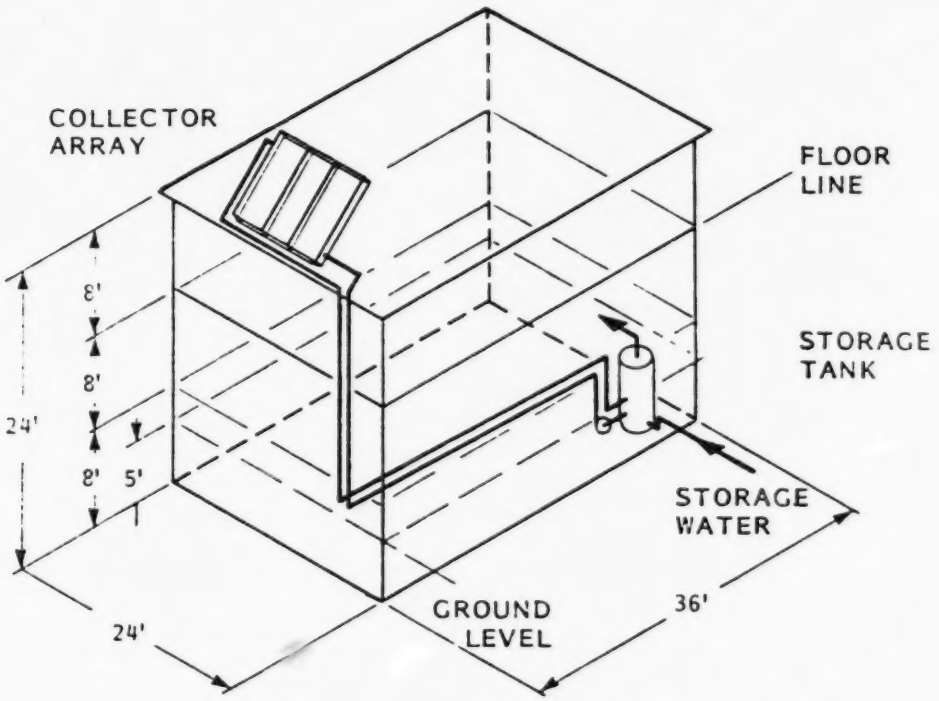
Item	Location			
	Interior		Exterior	
	Reference Code	Unit Cost ($/ft)	Reference Code	Unit Cost ($/ft)
Tubing	P1	0.77	P1	0.77
Insulation	PI3	1.30	PI5*	3.01
Jacket			J1	0.18
Total Cost		$2.07		$3.96

Hardware Structure Cost

Item	Reference Code	Number Needed	List Cost ($/pc)	Total Cost ($)
Gate valve	M4	2	10.37	20.74
Check valve	M4b	2	11.92	23.84
Fill/drain valve	N/A	2	8.00**	16.00
Air vent/vacuum	M2e	1	20.15	20.15
90° ell	R1i	10	0.96	9.60
45° ell	R1k	2	1.62	3.24
Coupling	R2a	8	0.70	5.60
Adapter	R1e	6	1.98	11.88
Miscellaneous @ 10% for solder, flux, etc				11.11
Total (less 40%)				$73.29

* less 53% for large purchases, all others less 40%
** assumed value

ISOMETRIC VIEW OF SDWHS PLUMBING LINES



NOTES:
- FLOOR AREA ≈ 800 FT²
- ROOF SURFACES ON 45° INCLINE
- 8 FT CENTRES BETWEEN FLOORS
- WATER SUPPLY AT FRONT OF BUILDING
- COLLECTOR ARRAY (≈ 9' X 8')
- WORST CASE SHOWN (EXAMPLE I)
  ALL LINES INSULATED
- ONE STORY DWELLING WOULD REQUIRE 16 FT LESS TUBING (PLUS INSULATION AND JACKET FOR OUTDOOR ENVIRNMENT)
- INDOOR HORIZONTAL LINES ARE FASTENED TO CEILING OF GROUND FLOOR.

INSTALLATION COSTS OF CONVENTIONAL SDWH SYSTEMS

Example	Number of Stories	Position of Major Components*	Location of Plumbing				Hardware Standard Cost ($)	Total Cost ($)
			Interior		Exterior			
			Length (ft)	Cost ($)	Length (ft)	Cost ($)		
I	2	Opposite side	78	162	58	230	73	465
II	1	Opposite side	78	162	42	166	73	401
III	2	Same side	20	41	58	230	73	344
IV	1	Same side	20	41	42	166	73	280
V	2	Opposite side	110	228	26	103	73	404
VI	1	Same side	50	104	26	103	73	280

* Location of storage tank with respect to collector array within the confines of the structure (See the isothermic view of SDWH Plumbing lines)

V and VI predominantly interior plumbing

POOR

QUALITY

ORIGINAL